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(54) **REFERENCE TIME DISTRIBUTION OVER A NETWORK**

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Related U.S. Application Data

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(51) **Int. Cl.**
H04J 3/06 (2006.01)
H04J 3/00 (2006.01)

(52) **U.S. Cl.** **370/503**; 370/520

(58) **Field of Classification Search** 330/241, 330/252, 498, 503, 508, 516, 517, 389, 400, 330/401, 402, 520
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,285,064 A *	8/1981	Hodge	455/13.1
5,530,846 A *	6/1996	Strong	713/400
5,621,895 A *	4/1997	Weis et al.	370/407
5,798,732 A *	8/1998	Eshenbach	342/357.12
6,032,261 A *	2/2000	Hulyalkar	713/400
6,199,169 B1 *	3/2001	Voth	713/400
6,275,544 B1 *	8/2001	Aiello et al.	375/326
6,370,138 B1 *	4/2002	Kim et al.	370/353
6,591,370 B1 *	7/2003	Lovett et al.	713/502
6,678,781 B1 *	1/2004	Domon	710/312
6,735,711 B2 *	5/2004	Lutz	713/500
6,778,543 B1 *	8/2004	Frouin et al.	370/402
6,914,895 B1 *	7/2005	Straub et al.	370/350
2006/0013223 A1 *	1/2006	Lym et al.	370/389

FOREIGN PATENT DOCUMENTS

GB EP 0946003 * 9/1999

(Continued)

OTHER PUBLICATIONS

Weidemann, Werner. "Application Critical Parameters for Rubidium Standards". IEEE. May 27-29, 1998. pp. 84-87.*

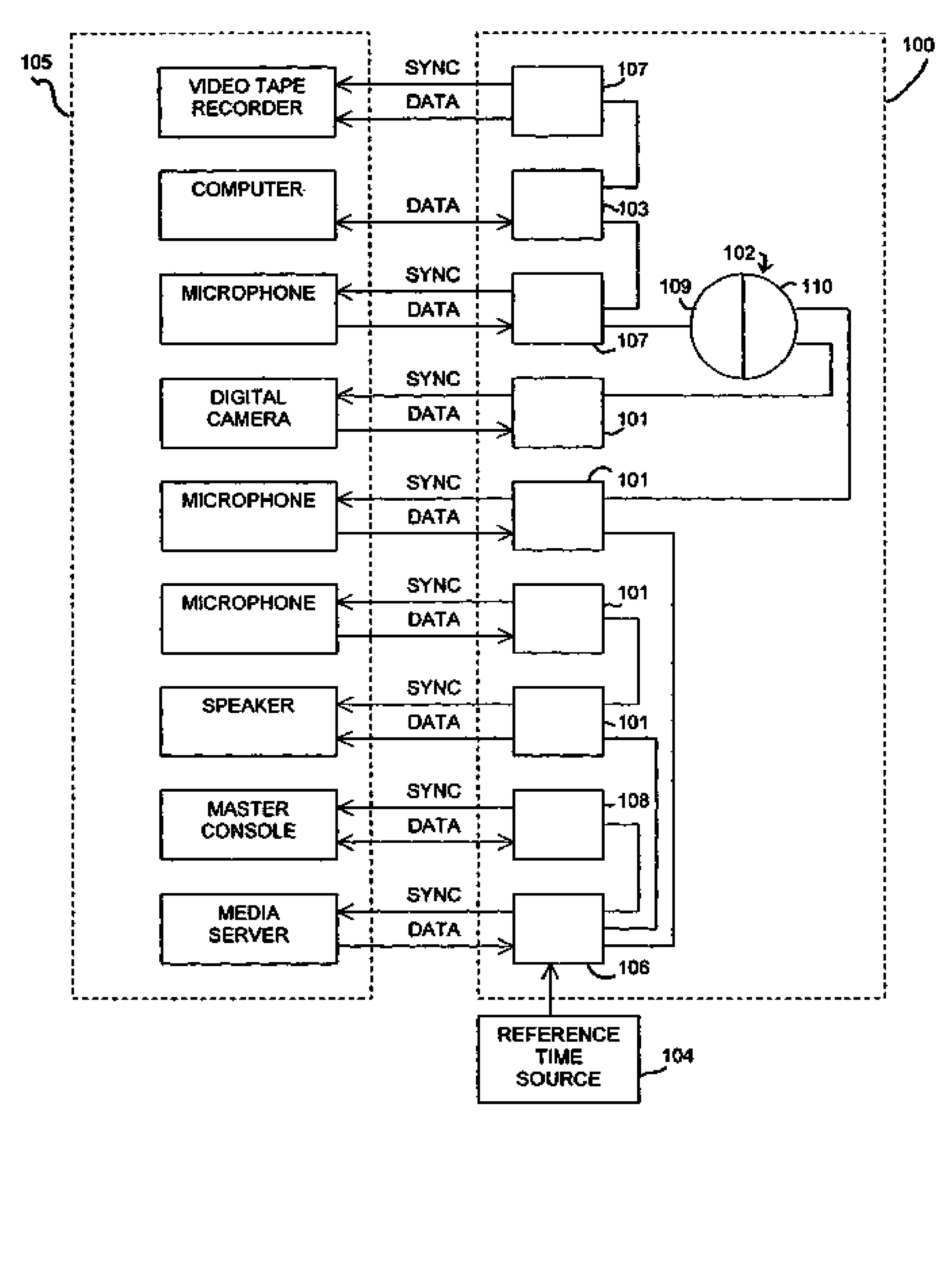
(Continued)

Primary Examiner — Ronald Abelson

(57) **ABSTRACT**

A reference time distribution system and method use a data transmission network having a plurality of nodes to distribute the House Sync signal. A network-wide time signal is generated using a reference time generator, and the network-wide time signal is then distributed over the network to the plurality of nodes. At each node, the network-wide time signal is converted to a local synchronization signal for use in performing synchronization of the timing of each node. Either network-inherent timing and/or additional time signaling is used to provide the nodes attached to this network with a network-wide notion of time. The time information is converted locally into synchronization signals or time information as required by a respective application. When data is transported over the network, delay compensation is performed to simultaneously output different data streams that have been synchronously input into the network, regardless of the data path.

16 Claims, 5 Drawing Sheets



FOREIGN PATENT DOCUMENTS

WO WO 99/55028 * 10/1999

OTHER PUBLICATIONS

"Enhancement to Audio and Music Data Transmission Protocol 1.0", TA Document 1999014, 1394 Trade Association, Santa Clara, California, U.S.A.; Jul. 10, 2000; 53 pages.
"Issues Related to Synchronization of Digital Media in IEEE 1394", Public E-mail Discussions of the Audio Engineering Society Standard Committee SC-06-02 Group, from Feb. 1, 1998 to Oct. 19, 1999; 113 pages.
"SMPTE Time Code and Sample Count Transmission Protocol Ver. 1.0", TA Document 1999024, 1394 Trade Association, Santa Clara, California, U.S.A.; Oct. 24, 2000; 22 pages.
A. Goldstein, "AES SC-06-02 Minutes Sep. 22, 2000", Meeting of the Audio Engineering Society Standards Committee; Sep. 22, 2000; 5 pages.
J. Fujimori et al., "Digital Audio Transmission Over IEEE 1394: Protocol Design and Implementation", 103rd Audio Engineering Society Convention, New York, New York, U.S.A., Sep. 26, 1997; 7 pages and 12 figures; Preprint No. 4547, published by the Audio Engineering Society.
H. Kuribayashi et al, "A Supplement to Audio and Music Data Transmission Protocol over IEEE 1394":, 105th Audio Engineering Society Convention, San Francisco, California, U.S.A., Sep. 26, 1998; 5 pages and 8 figures; Preprint No. 4762, published by the Audio Engineering Society.
R. Laubscher et al., "A 1394-Based Architecture for Professional Audio Production", 109th Audio Engineering Society Convention, Los Angeles, California, U.S.A., Sep. 22-25, 2000; 9 pages; Preprint No. 5246, published by the Audio Engineering Society.
B. Moses et al., "Audio Distribution and Control Using the IEEE 1394 Serial Bus", 103rd Audio Engineering Society Convention, New York, New York, U.S.A.; Sep. 26, 1997; 18 pages and 6 figures; Preprint No. 4548, published by the Audio Engineering Society.
M. Poimboeuf, "Hierarchical Protocol and Process for Synchronization of Isochronous Transfers on the IEEE 1394 Bus for Professional Audio and Video Media Data Streams", Draft AES-X60 Standard Proposal, Revision 0.0; May 11, 1998; 2 pages.
J. Strawn, "Current Situation, Future Work", Public E-mail to the Audio Engineering Society Standard CommitteeSC-06-02 Group; Apr. 12, 2001; 5 pages.
"Issues Related to Synchronization of Digital Media in IEEE1394", Public E-mail Discussions of the Audio Engineering Society Standard Committee SC-06-02 Group, from Feb. 1, 1998 to Oct. 19, 1999; 113 pages.

* cited by examiner

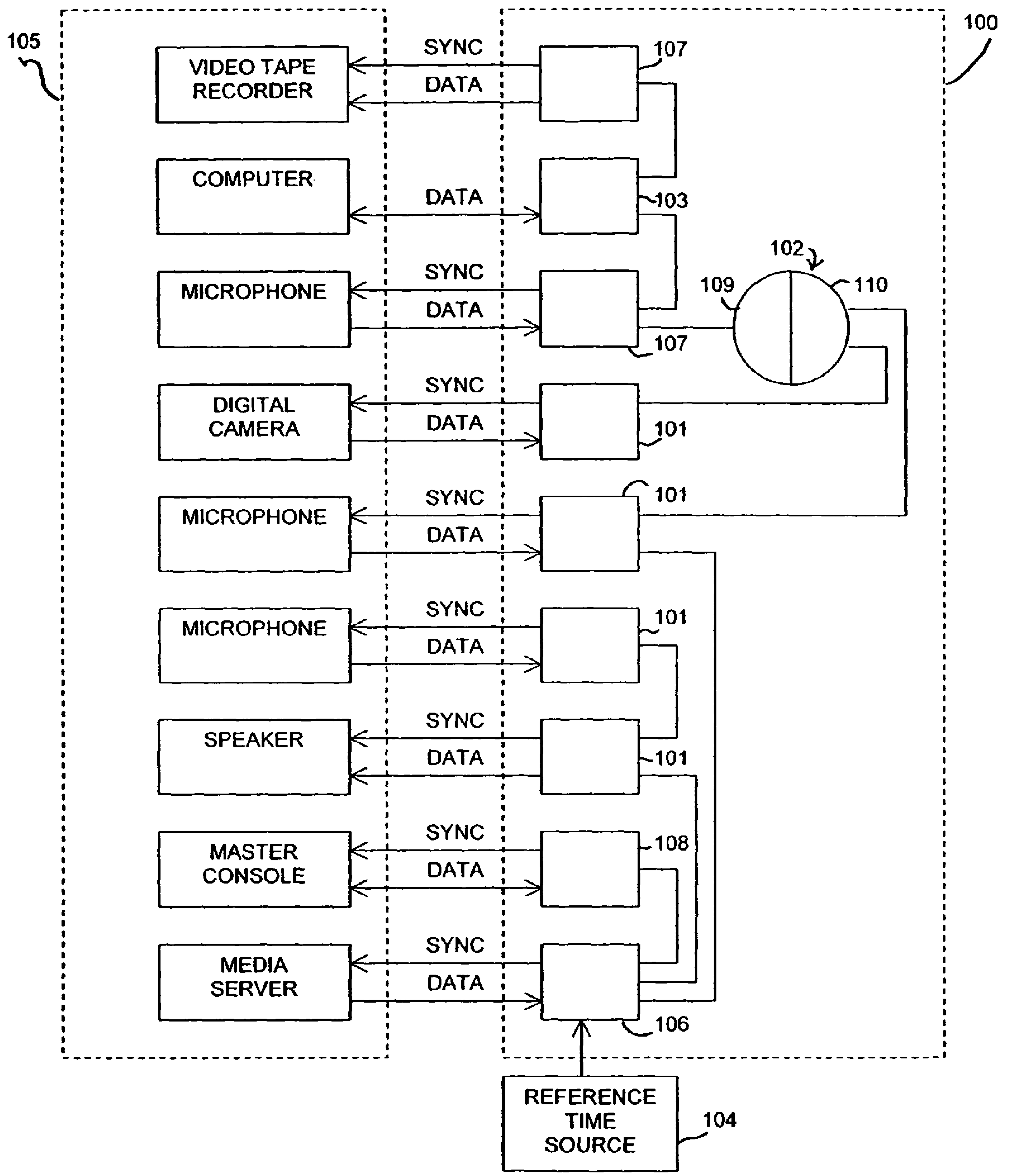

105
VIDEO TAPE RECORDER
COMPUTER
MICROPHONE
DIGITAL CAMERA
MICROPHONE
MICROPHONE
SPEAKER
MASTER CONSOLE
MEDIA SERVER
SYNC
DATA
100
107
103
102
109
110
101
108
106
REFERENCE TIME SOURCE
104

FIG. 1

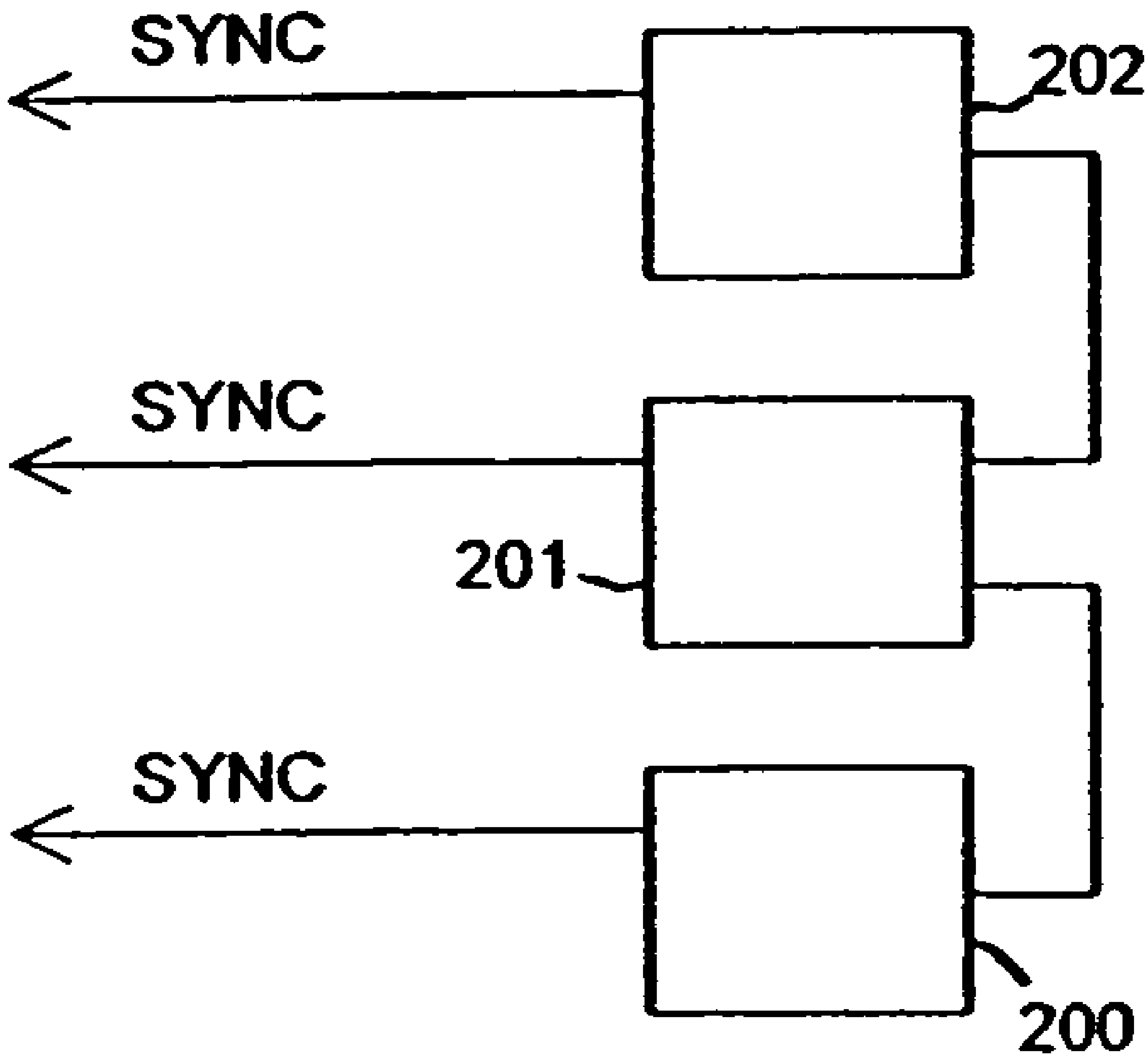


FIG. 2

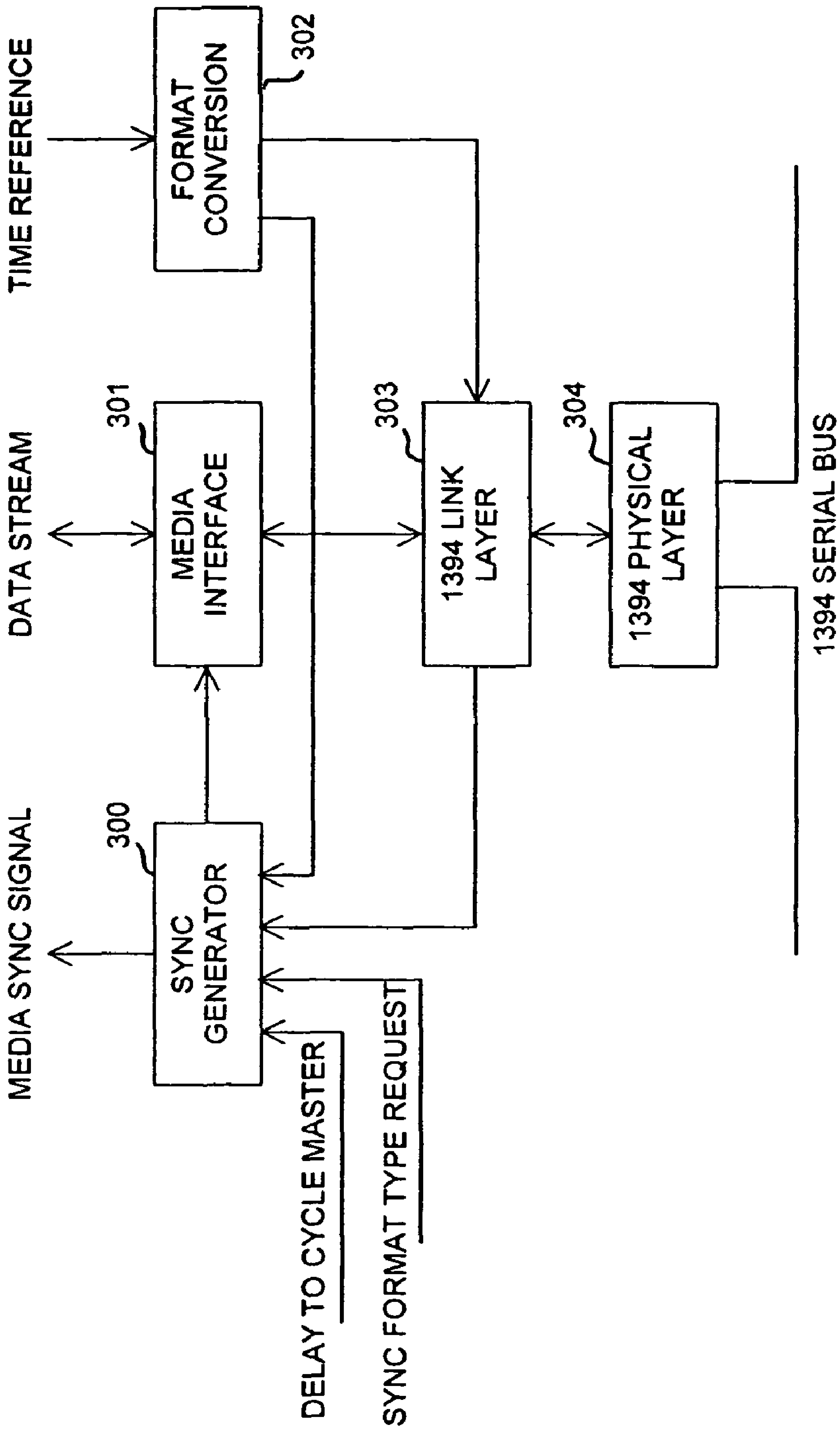

MEDIA SYNC SIGNAL
DATA STREAM
TIME REFERENCE
SYNC GENERATOR
300
MEDIA INTERFACE
301
FORMAT CONVERSION
302
1394 LINK LAYER
303
1394 PHYSICAL LAYER
304
1394 SERIAL BUS
DELAY TO CYCLE MASTER
SYNC FORMAT TYPE REQUEST

FIG. 3

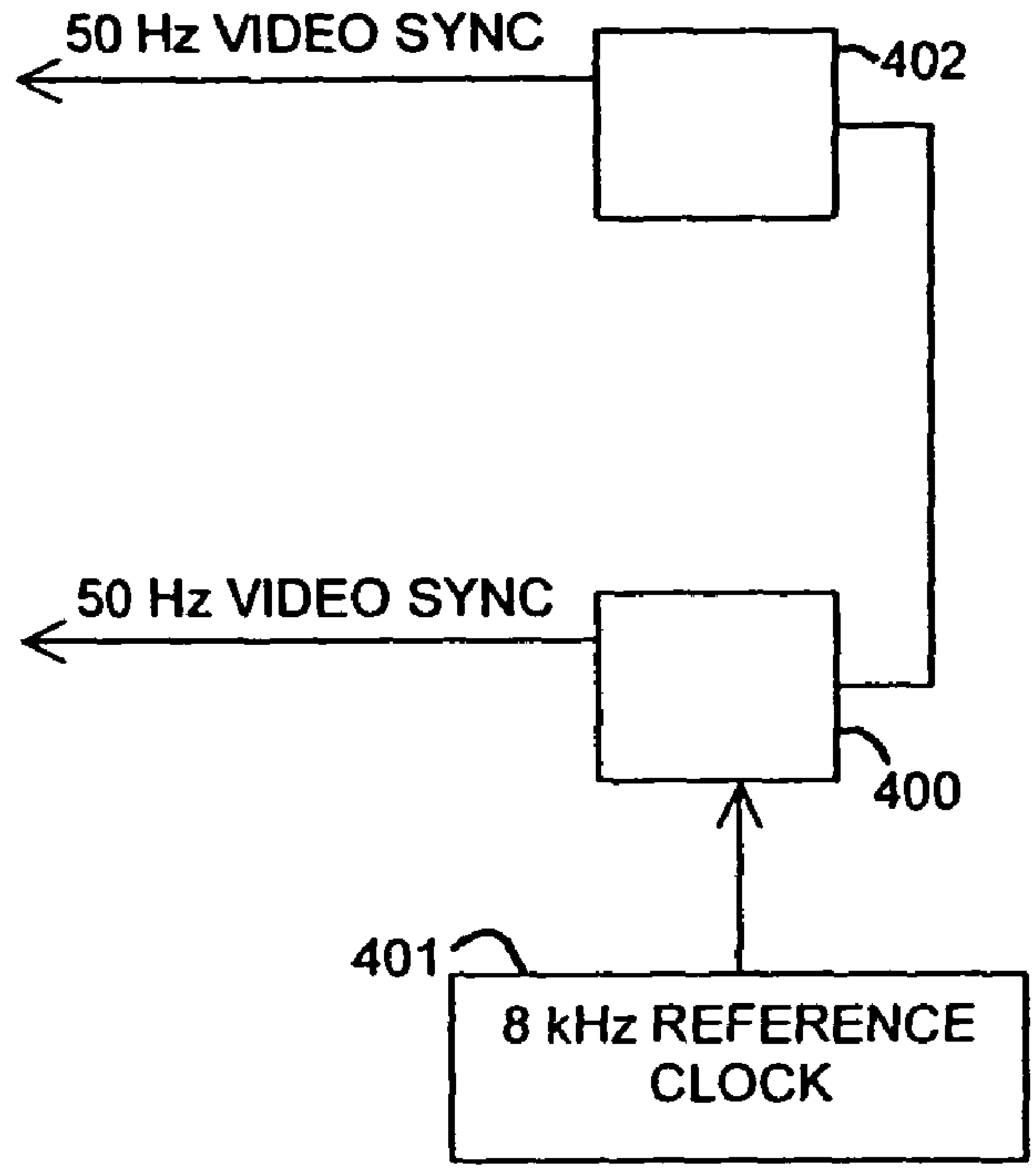

50 Hz VIDEO SYNC
402
50 Hz VIDEO SYNC
400
401
8 kHz REFERENCE CLOCK

FIG. 4

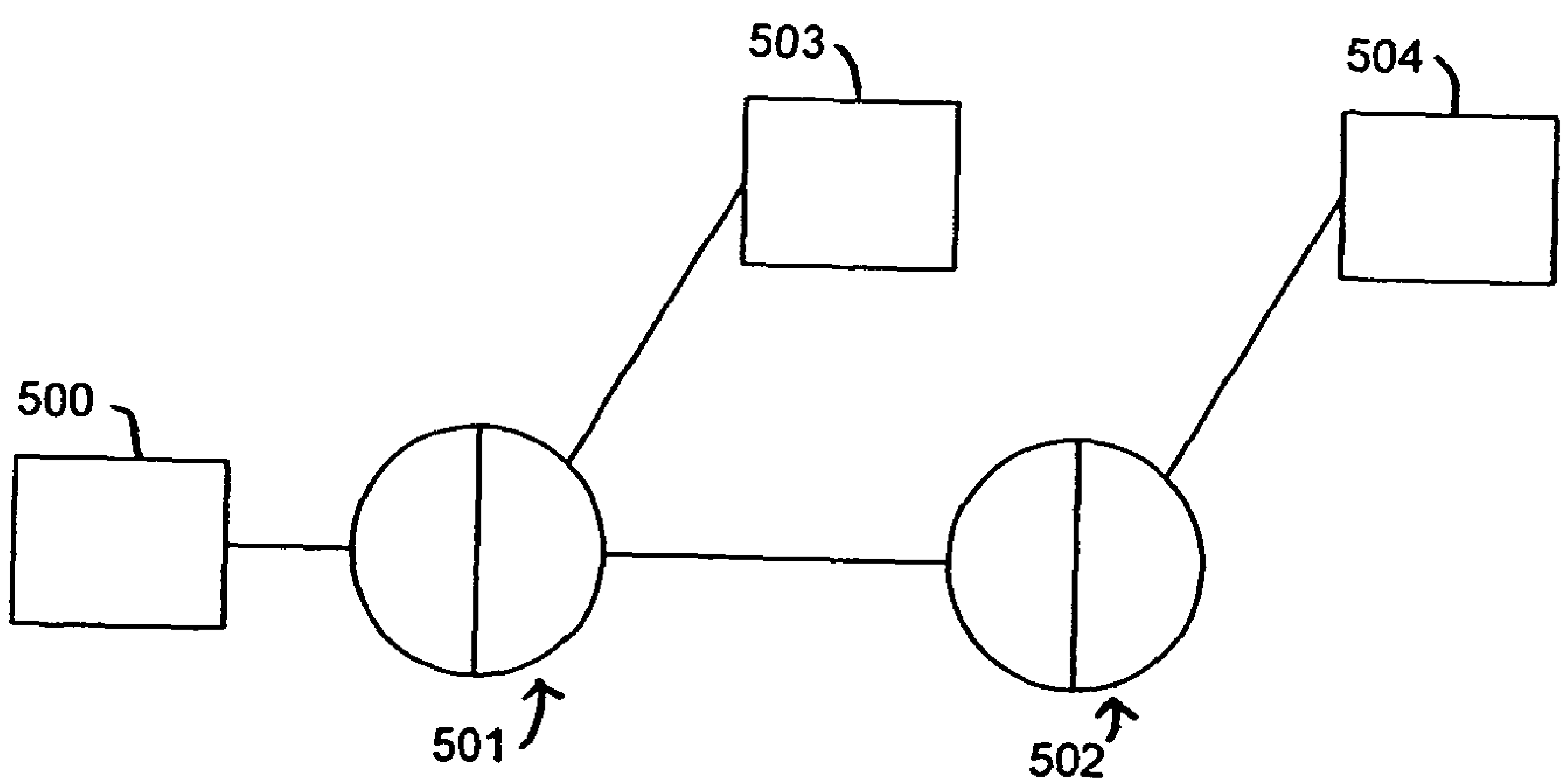

503
504
500
501
502

FIG. 5

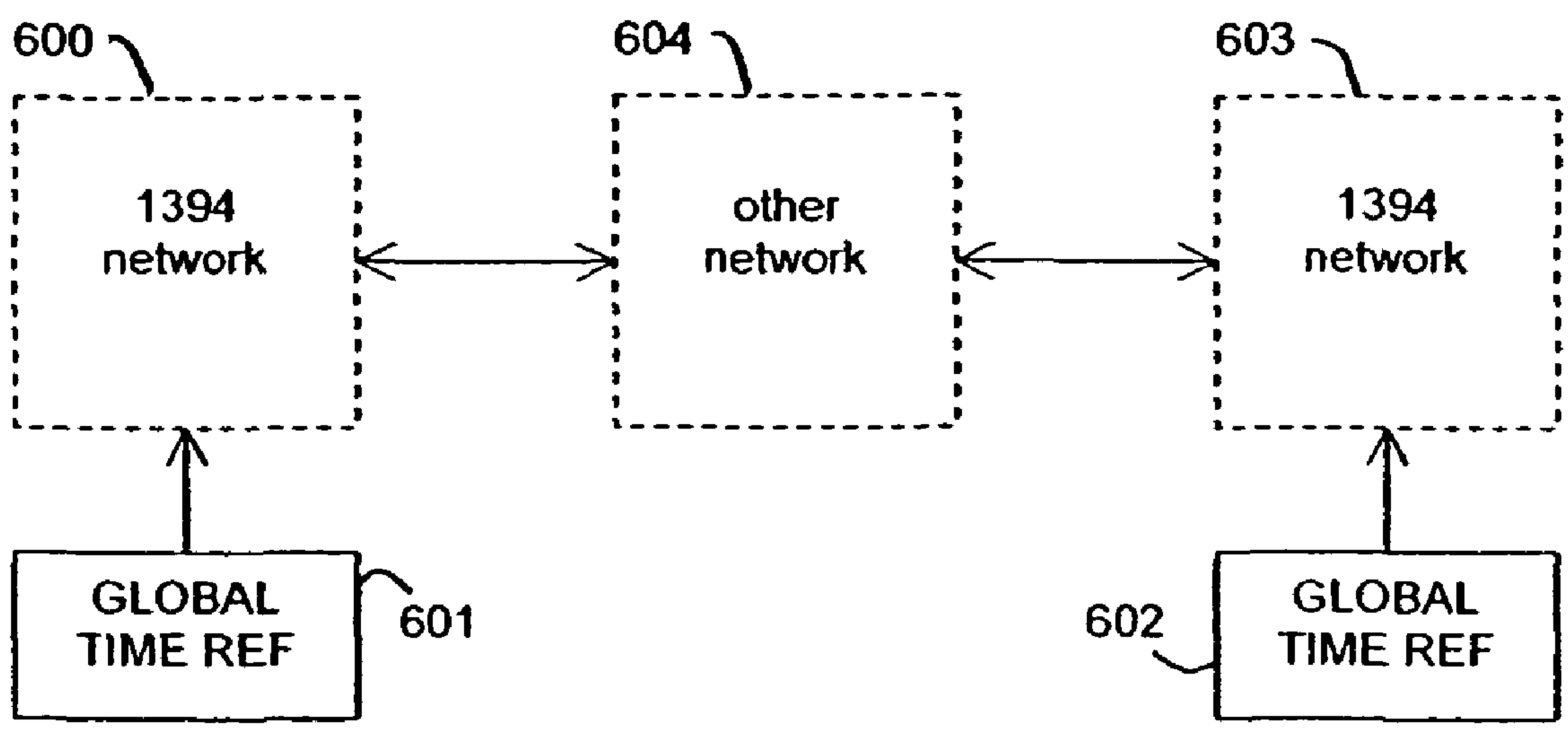

600
604
603
1394
network
other
network
1394
network
GLOBAL
TIME REF
601
602
GLOBAL
TIME REF

FIG. 6

REFERENCE TIME DISTRIBUTION OVER A NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to and claims priority from U.S. provisional application No. 60/183,617, filed Feb. 18, 2000, and to U.S. provisional application No. 60/246,012, filed Nov. 3, 2000, the specification of each provisional application being incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to the synchronization of devices contained within a synchronization domain. More particularly it relates to the provision of a reference time within a distributed network of diverse applications, including multimedia content production or entertainment equipment.

BACKGROUND OF THE INVENTION

Interconnected multimedia devices require at least pairwise links for the transmission of content information and mutual synchronization information. Most multimedia content production facilities provide dedicated links for the transport of content information to a master console for further integration or processing and the transport of a synchronization (sync) signal, commonly referred to as a House Sync signal.

The House Sync guarantees synchronicity of all connected devices. Different devices often require different frequencies or formats of synchronization signals. For example, audio sampling frequencies may be at 22.05, 32, 44.1, 48, 88.2, 96, 176.4, or 192 kHz, and video frame sync may occur at frame rates of 24, 25, 29.97 or 30 Hz. In a production facility, dedicated cabling is used to transmit one or more of these synchronization signals to every single device. This infrastructure relies additionally on central or distributed conversion units for the conversion between different synchronization signals or the regeneration of one or more synchronization signals. Use of conversion units must be planned carefully in order to avoid phase ambiguities.

Links for the transport of audio and video signals are mostly connections independent from the House Sync. With a growing number of interconnected devices, the connections in a content production facility becomes increasingly complex and requires careful planning. Rearrangement or extension of the infrastructure is often difficult to achieve.

A need exists for distribution of reference timing signals which avoids the disadvantages of the prior art, such as signal delays and complexity of the cabling of the network.

SUMMARY OF THE INVENTION

The disclosed reference time distribution system and method use a data transmission network having a plurality of nodes to distribute the House Sync signal and/or other synchronization signals. A network-wide time signal is generated using a reference time generator, and the network-wide time signal is then distributed over the network to the plurality of nodes. At each node, the network-wide time signal is converted to a local synchronization signal, and synchronization of the timing of each node is performed using the local synchronization signal.

Either network-inherent timing and/or additional time signaling is used to provide the nodes attached to this network with a network-wide notion of time. This time information is converted locally into synchronization signals and/or time information as required by a respective application. Synchronization signals of different types or frequencies are simultaneously distributed from different nodes within the network to applications or devices. Synchronization signals of the same type are phase aligned. Similarly synchronization signals of different type have a deterministic phase relationship. When data is transported over the same network, delay compensation may be performed to simultaneously output different data streams that have been synchronously input into the network, regardless of the data path.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates the distribution of a reference time signal over an IEEE 1394 serial bus and the provision of appropriate synchronization signals to a variety of media devices.

FIG. **2** illustrates a node set with timing phase correction.

FIG. **3** illustrates in more detail the internal fabric of an IEEE 1394 node with the capability of reference time distribution.

FIG. **4** illustrates the generation of multiple phase aligned synchronization signals with frequencies other than the frequency of a central frequency reference.

FIG. **5** illustrates delay compensation for aligned play-out of streams traveling paths with differing propagation delay.

FIG. **6** illustrates the synchronization of IEEE 1394 network islands via a network-wide time reference.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The disclosed reference time distribution system and method performs synchronization within a distributed network of multimedia content production or entertainment equipment, as well as for other applications such as content contribution, distribution, and/or broadcasting; consumer multimedia; control applications, etc.

As shown in FIG. **1**, the disclosed reference time distribution system and method are used in a network **100** of nodes **101**, **103**, **106**, **107**, **108**, **109**, **110**. The nodes **109** and **110** may function as portals for the network **100**, and the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** may be either connected directly to each other and/or having one or more network devices **102** with the nodes **109** and **110**, acting as portals, connecting the network segments to each other. The network **100** may include a plurality of such network devices, such as bridges, gateways, switches, routers, or other connections or interfaces between nodes and their associated applications and devices. When such network devices **102** are used between nodes, the nodes are not required to be identical and/or compatible with each other, since the network devices **102** may provide a bridging interface between different communications protocols and standards implemented in the nodes.

The plurality of network devices may be wired, wireless, or a combination thereof, so the overall network **100** may be a wired network, a wireless network, or a heterogeneous combination of wired and wireless components and communications channels. The information and signals transmitted over the network **100** may be electromagnetic, wireless, and/or data packets; for example, the distributed reference time signals or information may be transmitted over the network **100** as data packets.

The network **100** may be, in a preferred embodiment, an IEEE 1394-type network and as such the network **100** provides a mechanism for time distribution. In an IEEE 1394 bus, a single node, the cycle master **106**, transmits at regular intervals the contents of its cycle time register encapsulated in cycle start packets to all other nodes **101** within the same bus, overwriting their own cycle time register with the received value. Independent from cycle start packets, each node **101**, **103**, **106**, **107**, **108**, **109**, **110** increments its cycle time register by one at a nominal rate of about 24.576 MHz. In an IEEE 1394 network, formed of two or more buses, a single cycle master **106** takes the role of net cycle master.

Bridges **102** between buses detect differences between the cycle time registers of the cycle masters of adjacent buses. For example, referring to FIG. **1**, a first bus may be represented by the nodes **101**, **106**, **108**, **110** operating as one bus, and a second bus may be represented by the nodes **103**, **107**, **109** operating as another bus, with the first and second buses being adjacent buses. The bridges **102** then perform adjustment of the cycle master, for example, node **103**, of the bus that is further away from the net cycle master **106**. If the cycle master that needs to be adjusted is not contained within the bridge **102**, this adjustment is controlled by the transmission of cycle master adjustment packets from the bridge portal **109** to the cycle master **103**. The IEEE 1394 arbitration scheme ensures that a cycle start packet has access to the bus once in about every 125 μs. The exact time of transmission depends on the value of the cycle master's cycle time register and ongoing asynchronous traffic. Cycle start packets are delayed on their way from the cycle master to other nodes. This delay depends on the distance between cycle master **106** and the receiving nodes **101**, **108**, **110**, the number of nodes on the path in-between, and the individual hardware of each node involved in transmitting, forwarding and receiving the cycle start packet. This delay typically includes a significant jitter component, i.e. it is different for any two packets transmitted over the same path.

Each cycle start packet marks the start of a cycle within a bus. Following a cycle start, isochronous packets may be transmitted, followed by asynchronous packets. The periodic occurrence of cycle start packets guarantees a high level of quality of service, such as maximum latency, to isochronous packets. The value of a cycle time register is also used to timestamp video and audio streams as defined in the International Engineering Consortium (IEC) standards IEC 61883-1 through 61883-6.

A node receiving a media stream is enabled to recover the signal clock of the media source using the timestamp. Receiving nodes perform clock recovery independently for every stream. In a networked environment with many participating media devices, this situation requires a large number of clock recovery stages and leads to many different clocks, namely different signal clocks, the cycle clock of the underlying serial bus, and eventually the House Sync. Although some of these clocks may have identical nominal values, in the prior art, phase and frequency variations occur and cause poor alignment of previously strictly aligned media streams. The disclosed reference time system and method adjusts for such phase variation, as described herein.

A preferred embodiment of this invention makes further use of the cycle time register contents to derive synchronization signals in every node implementing the disclosed invention, independent from traffic over the IEEE 1394 network. It further implements measurement and compensation of the delay which a cycle start packets incurs when traveling from the cycle master to another node. This measurement relies on pinging, a method generally known in the art, but not with respect to this application. The conversion process from cycle time register contents to a synchronization signal also includes smoothing of cycle start packet delay jitter.

In one embodiment, a network-wide notion of time within each node **101**, **103**, **106**, **107**, **108**, **108**, **109**, **110** is obtained by reference to the values of cycle time and bus time registers of a unique node within the network **100**, such as the net cycle master **106** or the prime portal **110**. Referencing a unique node's cycle and bus time registers may rely on a local node's cycle and bus time registers, complemented by information about their differences to the unique node's cycle and bus time register values. A local node may update this information after it has detected or has been notified of a potential change of network time.

In a network containing bridges, bridge portals may assume the tasks of notifying local nodes about potential network time changes, and holding the required time information for retrieval by local nodes. Due to message propagation time, time differences between distant nodes are not readily available. The cycle time distribution process ensures approximate alignment of cycle time within a local bus. A subset of bus time is overlapping with cycle time, while another subset of bus time is independent for any node in the network. The distribution of network time uses the time difference information within network devices between buses to update timing information traveling across buses. Also, the overlapping of cycle and bus time is used to estimate and subsequently correct errors that may have been introduced by message propagation delay.

A reference time source **104** may be used in the network **100** to generate and provide a network-wide time signal to the network **100**, and in particular to a first node **106** of the plurality of nodes **101**, **103**, **106**, **107**, **108**, **109**, **110**. In one embodiment, the reference time source **104** may be a clock unit connected to the network **100**, with the clock unit including timing circuitry or signal generators operating independent of the rest of the network **100**. Alternatively, the reference time source **104** may be a clock or oscillator incorporated in an arbitrary node of the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** of the network **100**. The network **100** supports and transports both the reference time signal and data signals, without the need for additional infrastructure to segregate the paths of the reference time and data signals.

The individual nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** may generate local synchronization signals, as respective sync signals, from the network-wide time signal. The appropriate sync signal from a node, for example, node **108**, is transmitted to the applications or devices **105** connected to a particular node, such as the node **108**. It is to be understood that each node **101**, **103**, **106**, **107**, **108**, **109**, **110** may be connected by a single connection or multiple connections to the network **100**, for example, an IEEE 1394 network. In addition, it is to be understood that each node **101**, **103**, **106**, **107**, **108**, **109**, **110** may generate and output multiple synchronizations signals, including different synchronization signals for different applications **105** and devices. Furthermore, each node **101**, **103**, **106**, **107**, **108**, **110** may be connected to and/or have multiple interfaces to one or more applications **105** or devices, for example, depending on the type of application and its need for the node-generated synchronization signal or signals.

In alternative embodiments, some nodes, such as node **103** shown in FIG. **1**, may only transmit data and not transmit any synchronization signal; for example, node **103** may be a node or other network device not implementing reference time distribution. For example, node **103** may not have the requisite distribution configuration or circuitry, or may be configured to not distribute the network-wide reference time, or may have such distribution circuitry intentionally blocked or disabled from operating. In one embodiment, node **103** may represent a non-IEEE-1394-compatible network device which does not support or is incapable of such reference time distribution.

In another embodiment, node **103** may be a node dedicated to operate with specific devices which may not require such reference time distribution; for example, a stand-alone computer such as a personal computer (PC) or terminal, as well as a personal digital assistant (PDA) and/or other mobile, pure media, and/or multimedia devices, which may connect to the network **100** through the dedicated nodes **103** to receive data therefrom; for example, web pages over the Internet. In another embodiment, node **103** may include docking-ports for mobile devices and/or applications and devices **105** which exchange data in either direction to and/or from the network **100** through the node **103**, and which may be disconnected from the network **100** for independent operation.

The plurality of applications **105** may be multimedia devices such as a video tape recorder, a computer, a microphone, a digital camera, a speaker, a master console, a media server, equipment control devices, multimedia content production or entertainment equipment, etc., which receive the sync signal and/or an SMPTE/EBU timecode, and transmit and/or receive data signals from their respective nodes. Alternatively, one or more of the applications **105** may support pure media, such as audio only (pure audio) and/or video only (pure video), and/or other types of sensory communications signals, as well as fixed, dynamically changing, or selectable combinations thereof.

The applications **105** and/or devices may respectively be external, internal, or hybrid external/internal devices relative to the network **100**. For example, a given application, sets of applications, or the entire plurality **105** of applications may form one or more nodes of the network **100** as well, and so may be incorporated into the network **100**, such that the nodes **101**, **103**, **105**, **106**, **107**, **108**, **109**, **110** form a single entity. Accordingly, interfaces between the nodes, such as interfaces to the entity **105**, are not visible externally to other entities connected to the network **100** and/or to the applications of the entity **105**.

In a preferred embodiment, a IEEE 1394-compliant serial bus is used with the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** and/or the bridge **102** to integrate different digital data streams and/or data packets within a single network. Using isochronous streaming techniques known in the art, both a required transmission bandwidth and a maximum transmission delay are guaranteed.

The disclosed reference time system and method enable nodes on one or more interconnected IEEE 1394 serial buses to distribute the House Sync as the sync signal. One node within the IEEE 1394 network, for example, the node **106**, connected to the reference time source, issues a central synchronization signal derived from the reference time source **104**, implemented using an external clock source optionally having, for example, outstanding or substantially high precision as a rubidium-based reference, a global positioning system (GPS) reference, or a reference to a mains frequency known in the art. Alternatively, the reference time source **104** may have a relatively low precision and/or may be internal to any arbitrary one of the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** of the network **100**.

A serial bus node of the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** is configured in a manner known in the art, by software and/or hardware, to provide a desired format of the network-wide sync signal, so that the disclosed system and method simultaneously provide different local synchronization signals within an IEEE 1394-based network, to integrate both data transport and associated synchronization within an IEEE 1394 serial bus infrastructure. That is, each respective application **105** receives an appropriate sync signal from its respective node. An IEEE 1394 serial bus network so configured thus performs as a synchronous data transport network. Ease of scalability and cabling of the disclosed system and method are the same as for any IEEE 1394 serial bus network, and implementation of the disclosed system and method in a 1394 node does not prevent the node from being IEEE 1394 standard compliant. In addition, a standard compliant IEEE 1394 node not implementing the disclosed reference timing system and method does not prevent other nodes from providing the services enabled by the disclosed system and method.

Communication between multimedia devices **105** requires both data links and synchronization between interconnected devices. In a preferred embodiment of the present invention, data and synchronization information is carried over the network **100** using an IEEE 1394-type serial bus. In particular, the entire network **100** may be an IEEE 1394 serial bus-based network having the individual nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** and any bridges **102** with bridge portals **109** and **110**, interconnecting two or more serial buses. Nodes **101**, **106**, **107**, **108** implement the reference time distribution, and the reference time source **104** provides a stable timing signal to the net cycle master implemented in a specific node, such as node **106**, which distributes the cycle time over the network **100** for use by the other nodes **101**, **103**, **106**, **107**, **108**, **109**, **110**.

In an alternative embodiment, the net cycle master node **108** generates the cycle master signal, but a different node, such as node **106**, may adjust the net cycle master, with node **106** being the reference node of the network **100** although node **106** is not the net cycle master node. This adjustment process may use cycle master adjustment packets. In particular, the network **100** may be an IEEE 1394 network, with such configurations of the net cycle master node and the reference node being supported by the IEEE 1394 network.

Nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** derive local synchronization signals for their respective applications from cycle time and bus time information. Cycle time and bus time information may consist of both the values of a node's local cycle and bus time registers, as well as knowledge about these values within other nodes and knowledge about the difference between local and remote values. The reference time source **104** may be connected to any other node capable of propagating the network-wide reference time signal to one or more of the nodes **101**, **103**, **106**, **107**, **108**, **109**, **110** of the network **100**.

Referring to FIG. **2**, a subset of the network **100** is illustrated to describe the timekeeping functions of the disclosed system and method, with a single node **200** connected to other nodes, such as node or network device **201**, and in turn to another node **202** through the intervening node **201**. Timekeeping is performed by the exchange of cycle time and bus time information, or subsets thereof from a single node **200** to other nodes **201** and **202** in the IEEE 1394 network. Every node **200**, **201**, **202** tracks and stores the packet propagation delay between the cycle master and itself, and every node **200**, **201**, **202** respectively adjusts the phase of the synchronization output (sync signal) to its respective media application **105** or devices accordingly. The local synchronizations signals may have different frequencies, but two sync signals of identical frequency are phase-aligned regardless of their physical location. Thus phase alignment between the synchronization signals issued by different nodes to media applications and devices is achieved. Accordingly, the notion of time of each node **200**, **201**, **202** is unaffected by the packet propagation delay between nodes **200**, **201**, **202**.

Referring to FIG. **3**, the components of a typical node **101**, **103**, **106**, **107**, **108** are shown, in which a node includes a sync generator **300** connected to a media interface **301**, which in turn is connected to an IEEE 1394 link layer **303**. The link layer **303** is connected to a format conversion unit **302**, as well as to the sync generator **300** and to an IEEE 1394 physical layer **304**. The sync generator **300** receives the delay-to-cycle master signal as obtained by pinging, and a sync format type request to generate a media sync signal for a respective application or device **105** connected to the respective node. The sync signal is also provided to the media interface **301** for controlling the input and output of a data stream. The format conversion unit **302** receives the time reference signal as the network-wide time signal, and converts the signal to an appropriate signal format for use by the IEEE 1394 link layer **303**. The physical layer **304** is connected to the IEEE 1394 serial bus and thence to other nodes and/or bridges **102**.

Therefore, internally, a node's cycle and bus time information contained in the link layer **303** and the sync generator unit **300** is governed by an external time reference through the format conversion unit **302**. In a preferred embodiment, in the disclosed time distribution system and method, only a single node in the network **100** uses this path. In one embodiment, all other nodes in the network **100** either lack the format conversion unit **302**, or have the unit **302** deactivated or not implemented, so such nodes lacking a functioning unit **302** obtain cycle and bus time information over the IEEE 1394 serial bus via the physical layer **304**. The sync generator **300** generates the requested media sync signal upon cycle and bus time from the link layer **303** and knowledge of the propagation delay to the cycle master of the local bus and, eventually, knowledge of bus time and cycle time of remote nodes.

In another embodiment, for a reference node **106**, the format conversion unit **302** may be missing or deactivated, and the node **106** may use an internal reference clock of high or low precision to perform its functions. In alternative embodiments, for low precision applications, such propagation delays to the cycle master of the local bus may be ignored.

Referring to FIG. **4**, another subset of the nodes of the network **100** is shown to illustrate generation of the local synchronization signals to respective applications or devices **105**, as in FIG. **1**. The nodes **400**, **402** are connected to a reference clock **401** of a predetermined frequency. The reference clock **401** may be the reference time source **104** of FIG. **1**, or may be an independent reference clock. Alternatively, the reference clock **401** may derive its timing signals, such as an 8 kHz clock signal, from the reference time source **104** in a manner known in the art. Synchronization signals with frequencies that are non-integer multiples or rational fractions of the reference clock **401** are phase-locked to predetermined values of cycle and bus time of the nodes **400** and **402**, thereby removing the requirement for a lower frequency reference.

Referring to FIG. **5**, another subset of nodes is shown to illustrate delay compensation. For a node **500** transmitting a data stream as a "talking" node, the data stream may be routed over network devices **501**, **502**, which may be, in a preferred embodiment, IEEE 1394-compatible serial bus bridges. When several nodes **503** and **504** receive or "listen" to a data stream issued by a talking node **500**, and the path between talker and listeners is routed over network devices **501** and **502**, delay compensation is performed within the node **503** and/or the network devices **501** which are "nearer" to the talking node **500** by adding an extra signal delay. Such delay compensation is performed to guarantee simultaneous presentation of the streams, also known as aligned play-out, at nodes **503** and **504**; for example, for substantially simultaneous webcasts of news events over media-based nodes.

Alternatively or in addition, such delay compensation over the network **100** is used to facilitate simultaneous recording, aligned capture, and/or aligned "play-in" of data from streams or sources via the nodes **503**, **504** and/or their associated applications **105** and devices.

Referring to FIG. **6**, multiple time references **601**, **602** may be used to facilitate synchronization of networks **600**, **603** of one type with each other, even though the networks **600**, **603** may be "islands", separate from each other yet connected by a network **604** of a second type which may not support or transport reference timing signals. Time references **601** and **602** are aligned by known synchronization techniques or methods, such as synchronization schemes which are not part of the networks **600**, **603**, **604** such as, for example, the global positioning system (GPS). For example, the networks **600**, **603** may be IEEE 1394-compliant networks which are interconnected by a network **604** that is not IEEE 1394-compliant and/or not capable of transporting reference timing signals. Alternatively, one or more of the networks **600**, **603** may be non-IEEE 1394-compliant networks which may transport reference timing signals, while the interconnecting network **604** cannot transport such reference timings signals. However, the applications or devices connected to nodes of the network **600** may be synchronized to the applications or devices of the network **603** using a common timing reference provided by the time references **601** and **602** of each associated network, instead of local time references.

That is, using the time references **601**, **602**, the disclosed reference time distribution system and method implement networks **600**, **603** which do not require a compatible connection therebetween to support or transport such time references **601**, **602**. Thus, reference time distribution may be performed across heterogeneous networks having segments or devices of different types and/or complying with different communications standards or protocols. For example, reference time distribution may be performed over and between an IEEE 1394 network connected to an Ethernet, 802.3, or other local area network (LAN), metropolitan (or medium) area network (MAN), or wide area network (WAN), and so disparate devices may be networked and may use the reference time signals for synchronization and aligned play-out of data streams to diverse applications on either network.

In alternative embodiments, the network **604** in FIG. **6** may be a non-IEEE 1394 network able to or enabled for transporting a reference time, for example, using an Ethernet-based or 802.3-based network device, so in such alternative embodiments, a single network-wide time reference signal may be used, as in FIG. **1**, and so the time reference source **602** provided in the configuration in FIG. **6** is no longer required.

What is claimed is:

1. A method for distributing a reference time in a network having a plurality of nodes, the method comprising the steps of:

generating a network-wide time signal using a reference time generator;

distributing the network-wide time signal over the network to the plurality of nodes wherein each node is configured to generate different synchronization signals for different applications connected thereto;

measuring a signal propagation delay of the network-wide time signal between the reference time generator and each of the plurality of nodes, the step of measuring further characterized by the steps of:

maintaining a network-wide time signal as a network cycle master signal at a designated cycle master node of the plurality of nodes of the network;

maintaining a local cycle master signal at each respective node of the network; and

determining the signal propagation delay at each respective node from the difference between the respective local cycle master signal and the network cycle master signal;

generating, at each respective node, local synchronization signals using the measured signal propagation delay of the respective node, each of the generated local synchronization signals being required by a respective application; and

synchronizing the timing of each node for the respective applications using the respective local synchronization signals.

2. The method of claim **1**, characterized in that the network cycle master signal and each local cycle master signal is stored in a respective network cycle master register and local cycle master register, at each respective node.

3. The method of claim **1**, characterized in that the network-wide time signal is a house synchronization (synch) signal.

4. The method of claim **1**, characterized in that the local synchronization signal has an associated frequency.

5. The method of claim **1**, characterized in that the step of synchronizing includes the step of:

phase locking the local synchronization signal to a predetermined cycle value.

6. The method of claim **1**, characterized in that the step of synchronizing includes the step of:

performing delay compensation at each respective node.

7. The method of claim **6**, characterized in that the delay compensation is performed by adding an extra signal delay to the local synchronization signal.

8. The method of claim **1**, characterized in that the plurality of nodes includes:

at least one IEEE 1394-compliant node.

9. The method of claim **1**, characterized in that the step of generating the network-wide time signal includes the step of:

utilizing a rubidium reference signal generator.

10. The method of claim **1**, characterized in that the step of generating the network-wide time signal includes the step of:

utilizing a global positioning system (GPS)-based reference signal generator.

11. A system comprising:

a network including a plurality of nodes and a reference time generator for generating a network-wide time signal, wherein a designated node of the plurality of nodes is connected to the reference time generator, and has means adapted to distribute the network-wide time signal over the network to the plurality of nodes,

characterized in that each node of the plurality of nodes of the network has means adapted to generate different synchronization signals for different respective applications connected thereto and measure a signal propagation delay of the network-wide time signal between the reference time generator and each node and generate a local synchronization signals using the measured signal propagation delay, as required by the respective applications, and has means adapted to synchronize the timing of each node for the respective applications using the local synchronization signals, and further characterized in that the designated node has means adapted to maintain the network-wide time signal as a network cycle master signal; and each respective node of the plurality of nodes has means adapted to maintain a local cycle master signal and has means adapted to determine a respective signal propagation delay at each respective node from the difference between the respective local cycle master signal and the network cycle master signal.

12. The system of claim **11**, characterized in that the designated node includes a network cycle master register for storing the network cycle master signal and each node of the plurality of nodes of the network includes a respective local cycle master register for storing the local cycle master signal.

13. The system of claim **11**, characterized in that the plurality of nodes includes:

at least one IEEE 1394-compliant node.

14. The system of claim **11** being adapted for facilitating timing functions in a network (**100**), the system characterized by:

each node having means adapted to perform local timing control; and

a plurality of applications using timing functions under local timing control, with each node of the plurality of nodes associated with at least one application

wherein each node of the plurality of nodes of the network has means adapted to synchronized the at least one application associated with the respective node using the local synchronization signal.

15. The system of claim **14**, characterized in that the designated node has means adapted to maintain the network-wide time signal as a network cycle master signal in a network cycle master register; and

each node has means adapted to track signal propagation delay using the network-time signal, and has means adapted to convert the network-time signal by generating the local synchronization signal using the signal propagation delay of the respective node, to maintain a respective local cycle master signal in a respective local cycle master register, and to determine a respective signal propagation delay at each respective node from the difference between the respective local cycle master signal and the network cycle master signal.

16. The system of claim **14**, characterized in that the plurality of nodes includes: at least one IEEE 1394-compliant node.

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